THERMAL & FLUIDS ANALYSIS WORKSHOP

GSFC · 2015

SAGE III Lessons Learned on Thermal Interface Design

Warren Davis and Kaitlin Liles

NASA Langley Research Center (LaRC)

Kimberly Martin

Northrop Grumman

Outline

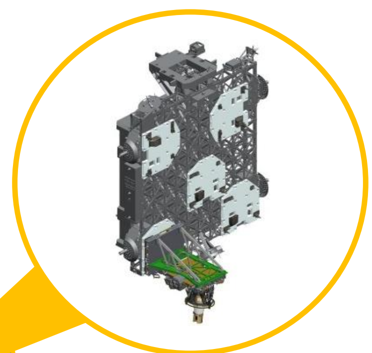
- Background
  - SAGE III on ISS
  - Interface Adapter Module (IAM)
- Evolution of IAM-ExPA Thermal Interface
  - Introduction to Thermal Interface Materials
  - Baseline Configuration
  - 2nd Design Iteration
  - Thermal Pad Testing
  - Final Configuration
- Lessons Learned

SAGE III on ISS Overview

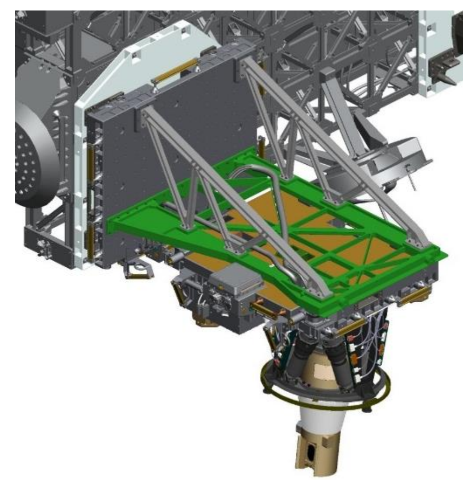
- Atmospheric science payload set for delivery to ISS via Space X Falcon 9 launch vehicle in 2016
- Fifth in a series of instruments developed to monitor ozone and other trace gases in Earth’s stratosphere and troposphere
- Three year minimum lifespan, five year goal

S3 Truss Payload Attachment System-4 Site (PAS-4)

ExPRESS Logistics Carrier-4 (ELC-4)

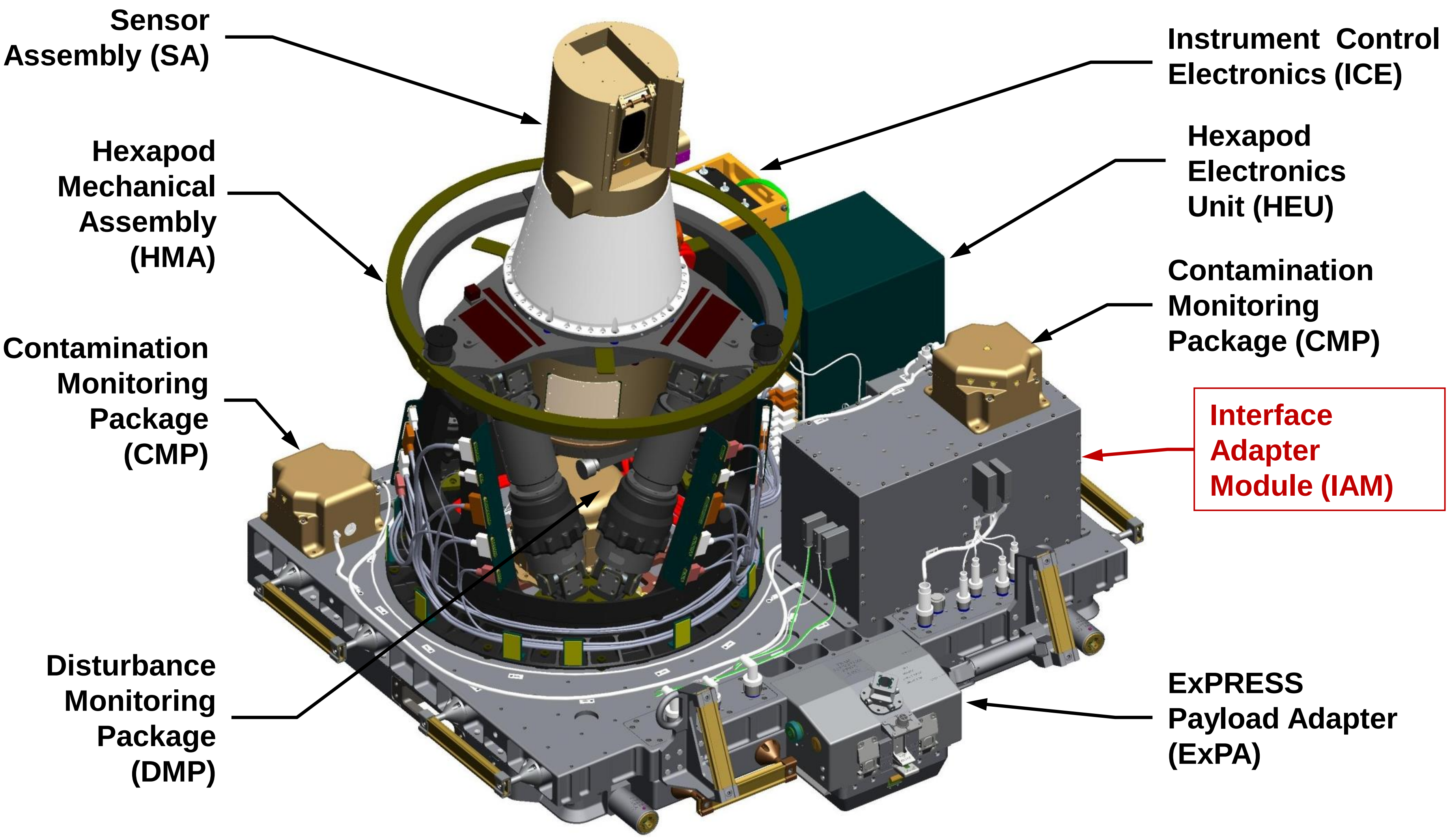


Passive FRAM Adapter Plate Site 3 (PFAP-3)



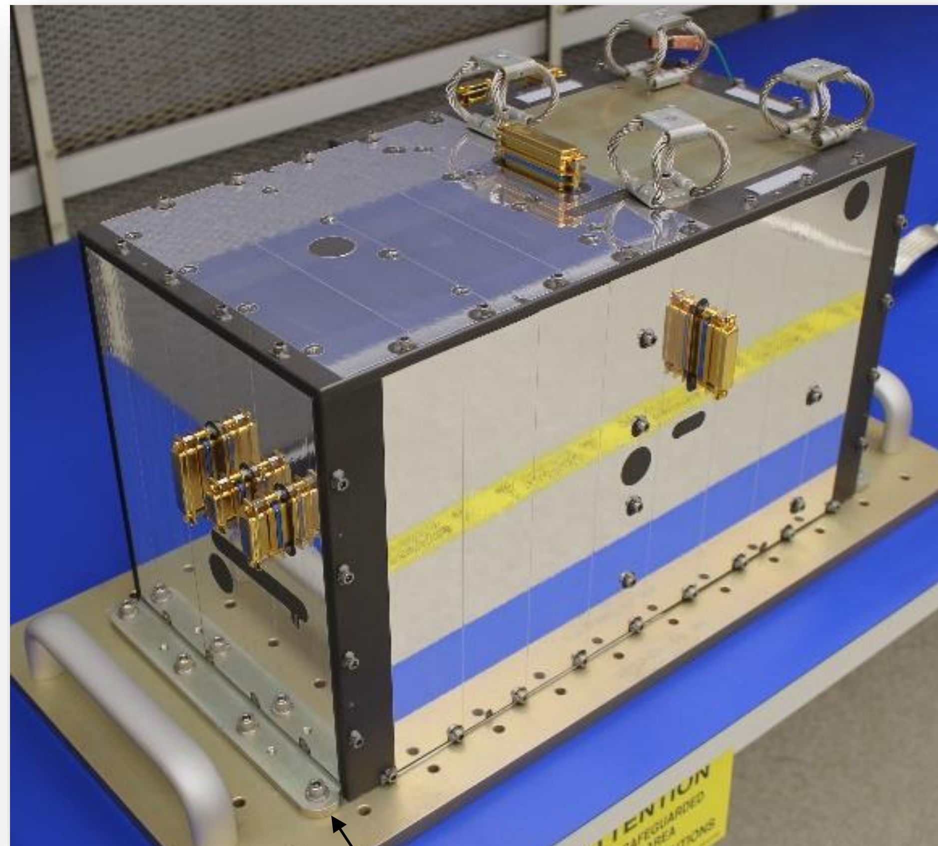
SAGE III On-Orbit Configuration

Instrument Payload



Interface Adapter Module

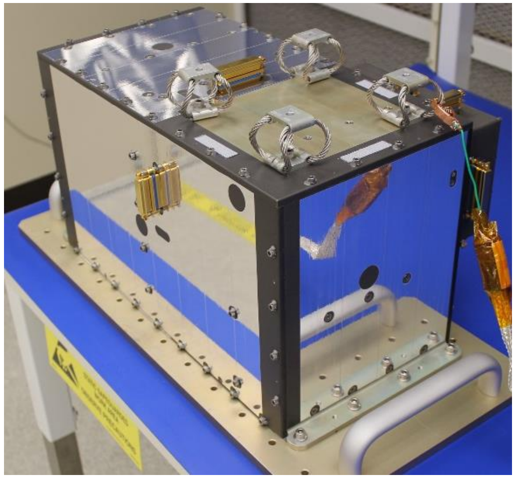
- Serves as on-orbit flight director of Instrument Payload
- Surface properties: AgFEP + MLI
- Power dissipation: +100 W (max design)
- Expected on-orbit operational temperature range: -5°C to +40°C

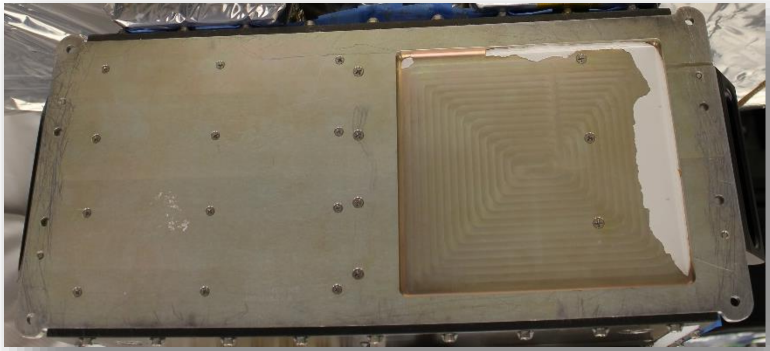


IAM mounting flange

Interface Adapter Module (cont'd)

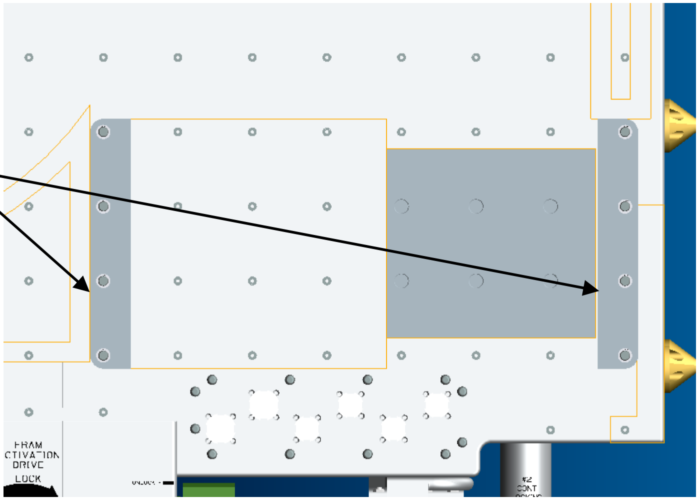
- Design Challenges:
  - Heat rejection via radiation alone insufficient
  - Conduction through dry IAM-ExPA interface also insufficient
  - Large span between fasteners (approx. 20")
  - Rigid footprint area (no room for expansion)
  - Measured flatness variation larger than expected
- Driving IAM-ExPA Interface Requirements
  - High thermal and electrical conductance (for grounding purposes)
  - Low outgassing, silicone-free materials





Underside of IAM baseplate

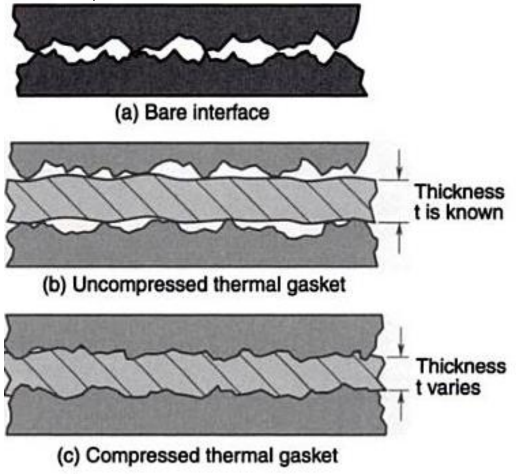
IAM fastener locations on ExPA



Interface Materials – What, When, Why?

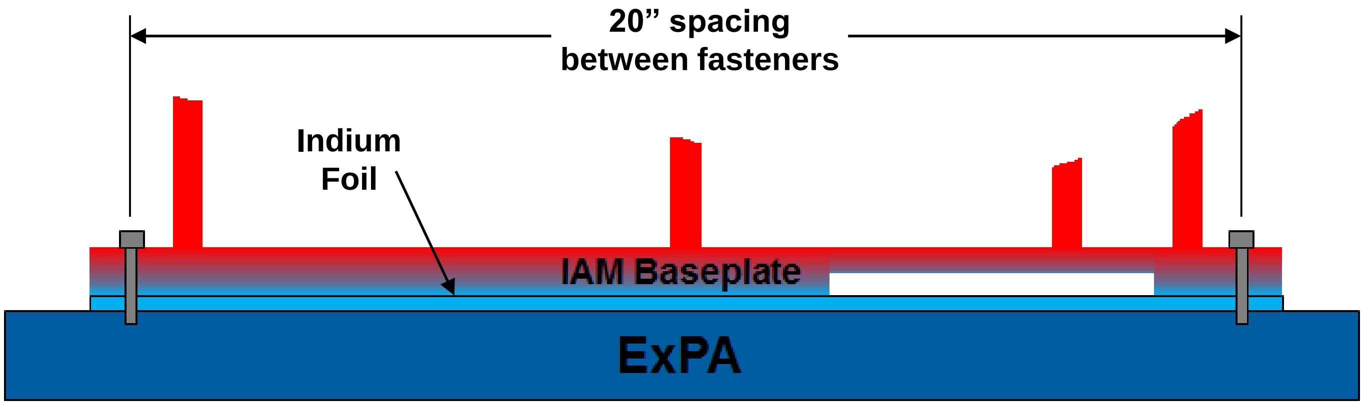
- What is a thermal interface material (TIM)?
  - TIMs, or "gap fillers", refer to any material placed between objects with the intent of increasing the thermal conductance through the interface
  - Very common; a large assortment of TIMs are readily available and include compressible metals, elastomerics, epoxies, thermal grease, and more
  - Increases contact area > increases conductance > decreases delta T through interface
- When should you use them?
  - Any time low thermal resistance is desired through an interface, but is not achievable or guaranteed from bare contact
  - Example applications:
    - Connecting heat generating components to heat sink
    - Attaching heat pipes or thermal straps to radiator
    - Mounting electronics boxes, TECs, many more
- Why should you use them?
  - Can remove uncertainty and increase confidence in analysis
  - Many are relatively low cost, widely available, and easy to implement

Credit: Spacecraft Thermal Control Handbook, Vol. I



Baseline Interface Configuration

- Baseline Configuration
  - Bolted interface with 99.9% indium foil, 0.010” thick
  - Chosen for its high conductivity (~80 W/m-K) and space flight heritage

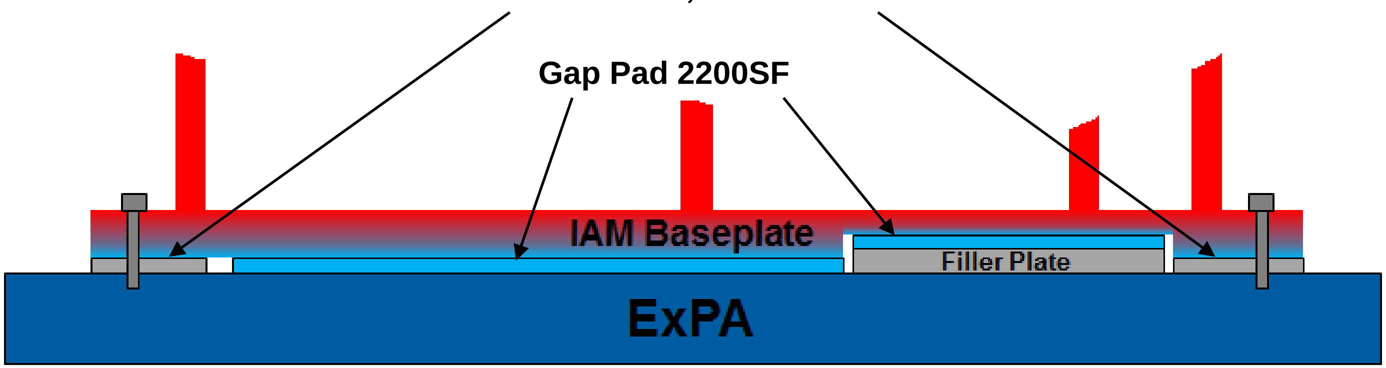


Cross-sectional *view of IAM-ExPA interface*

- Concerns:
  - Indium is subject to cold flow, resulting in a loss of preload over time due to thermal cycling, vibration testing
  - By covering blind holes in ExPA, potential for entrapped gas is introduced

2nd Design Iteration

- Replaced indium foil with Gap Pad 2200SF
  - Silicone-free thermal pad available in a wide range of thicknesses; good conductance when compressed
- Added 0.016” thick metal shims to control pad compression (not to exceed 40% of original thickness) and to provide grounding path
- Added filler plate to increase contact area based on results of trade study



Cross-sectional view of IAM-ExPA interface, 2nd iteration.

- Concerns
  - Previous experience suggested possible issue with high vacuum environment
  - No known spaceflight heritage

Gap Pad Performance Testing

- Subjected uncompressed and compressed GP 2200SF specimens to < $1e^{-5}$ Torr and 100°C for approximately 72 hours
- Specimens were compressed to 10%, 30%, 50%, and 70% compression
- Following bakeout, test specimens were tested for thermophysical properties testing (ρ, C_p, k) then compared to virgin material

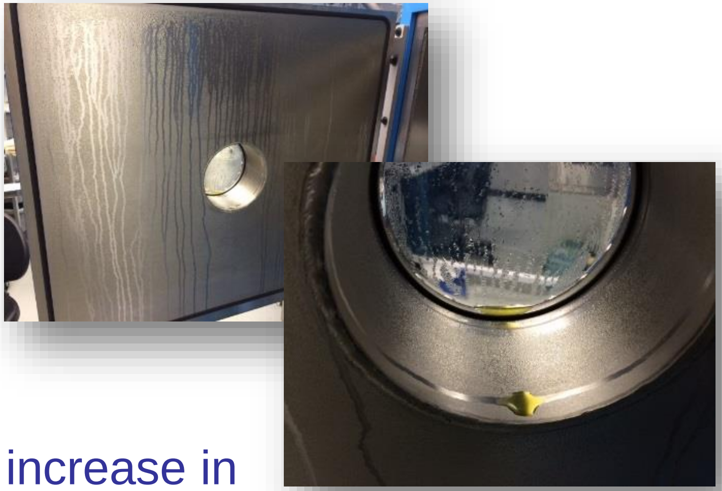
Cascade oven

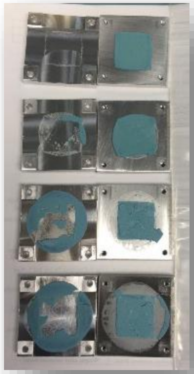
Compression plates

Material specimens in oven

Gap Pad Performance Test Results

- After 72 hours, yellow condensate formed on oven surfaces
- Uncompressed material specimens became hard and brittle and experienced up to 80% increase in conductivity compared to virgin material
- Compressed specimens retained elasticity (diffusion-limited) and experienced up to 30% increase in conductivity compared to virgin material
- Concluded that GP 2200SF was not well suited for the SAGE III mission environment





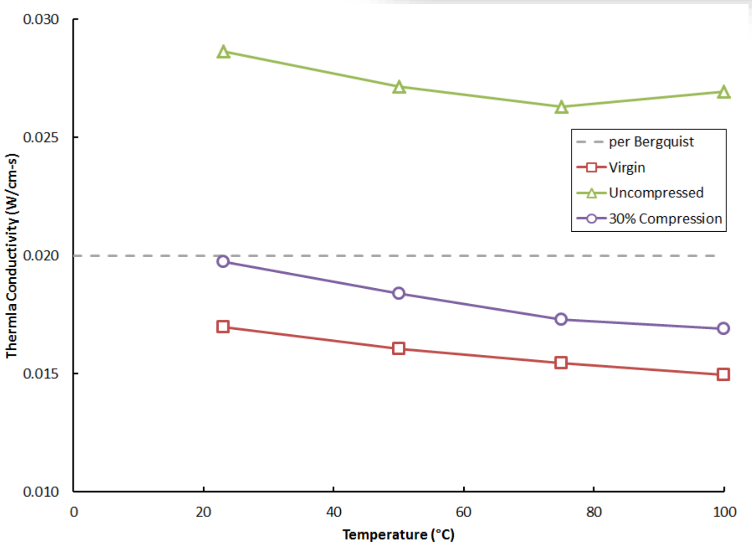
10%

30%

50%

70%

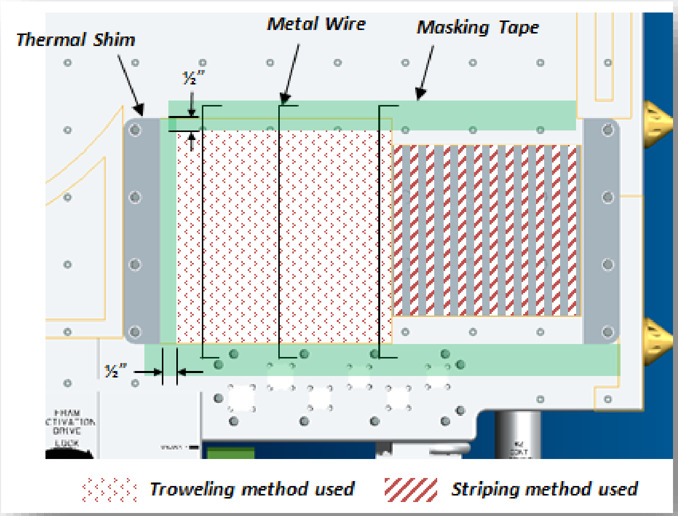
Compressed specimens

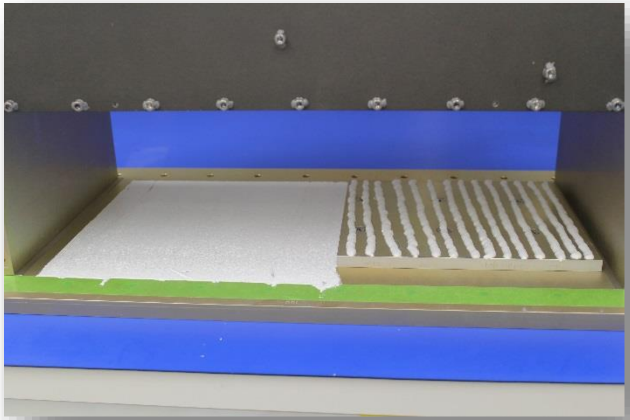


GP 2200SF thermal conductivity test results

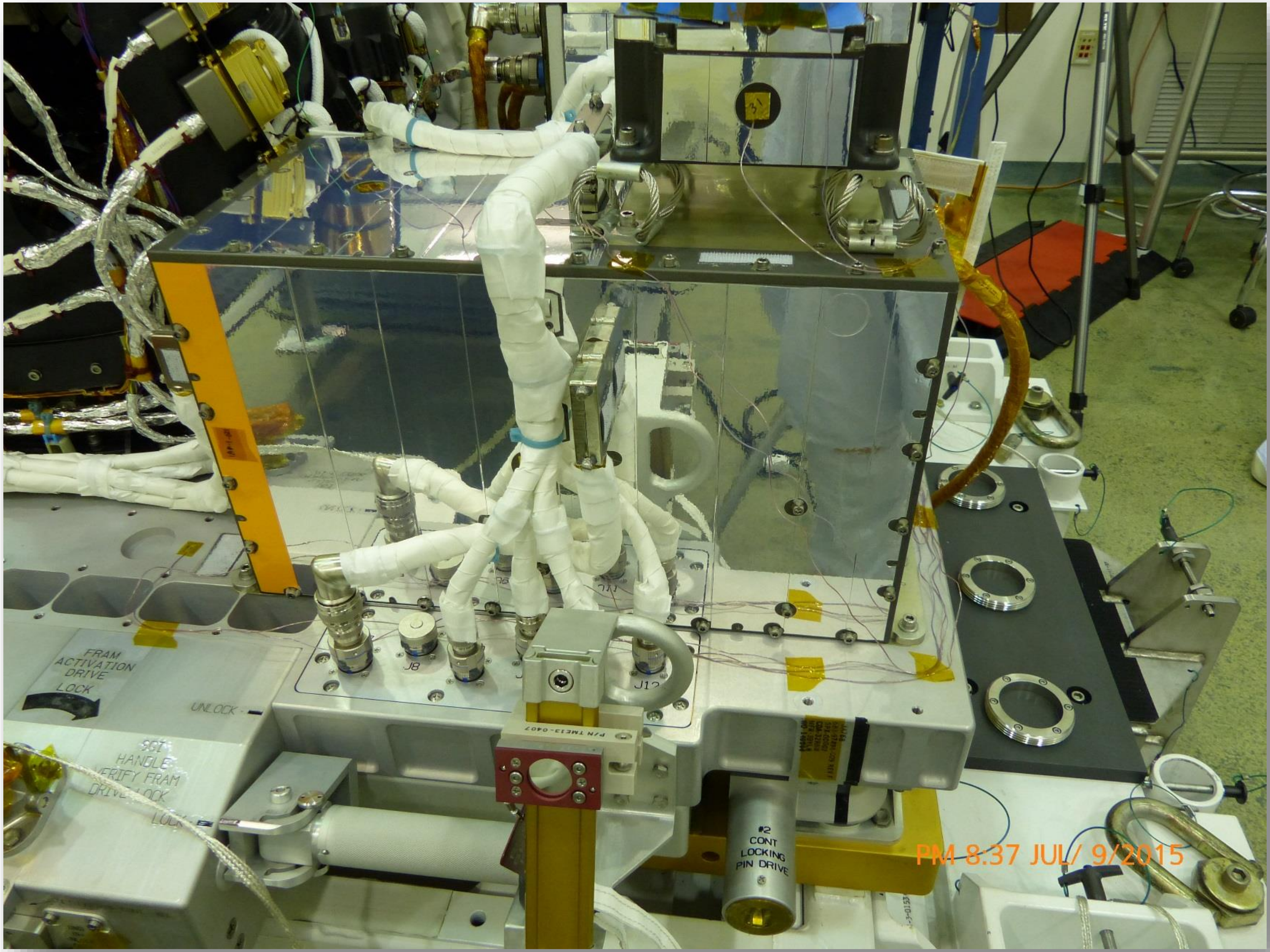
Final Interface Configuration

- Replaced GP 2200SF with NuSil CV-2946
  - Thermally conductive, platinum impregnated silicone
  - Lots of spaceflight heritage, good thermal conductance
  - Easily removed from flight hardware without release agent (in absence of primer)
- SAGE team members traveled to GSFC for hands-on NuSil application training
- Performed several practice applications to develop procedure
- Used a combination of application methods:
  - Troweling/screeding method over large acreage
  - Striping method over filler plate
- NuSil interface configuration verified during subsystem-level thermal-vacuum testing
- IAM was successfully integrated with Instrument Payload





IAM Integrated with Instrument Payload



Lessons Learned

- Collaborate with other disciplines on the team early in the design phase to ensure thermal considerations are taken into account
- Selecting interface materials with proven track record has its advantages
- Avoid large distances between fasteners
- Tight flatness and surface roughness specification can minimize thickness of interface material and increase available options
- Beware of cold flow when using indium foil; may experience loss of preload during thermal cycling or vibe
- Gap Pad 2200SF loses much of its elasticity from outgassing during bakeout testing, but increases in conductivity